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Pulse-Flow-Assisted Chemical Vapor Deposition Growth of Large-Area Two-Dimensional $MoSe_2$

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Abstract: Scalable synthesis of large-area, high-quality two-dimensional (2D) transition metal dichalcogenides (TMDs) remains a critical challenge for their integration into next-generation electronic and optoelectronic devices. In this work, we demonstrate a pulse-flow-assisted chemical vapor deposition (CVD) strategy for the controlled growth of large-area monolayer MoSe□. The approach involves periodic switching of the carrier gas between ON and OFF states during growth, which enables precise regulation of precursor supersaturation, mass transport, and surface reaction kinetics. This dynamic control effectively suppresses excessive nucleation while promoting sustained lateral domain growth, in contrast to conventional continuous-flow CVD conditions. Optical microscopy analysis reveals a significant enhancement in monolayer domain sizes, reaching lateral dimensions of approximately 50–100 µm on various substrates, indicating the robustness and substrate versatility of the method. Raman spectroscopy confirms the characteristic vibrational modes of monolayer MoSe□ with minimal strain and disorder, while photoluminescence measurements exhibit strong and uniform emission, further validating the high crystalline and optical quality of the as-grown films. Importantly, the pulse-flow technique is promoter-free, simple to implement, and readily scalable, making it highly compatible with existing CVD systems. This work provides an effective and general pathway for the controlled synthesis of large-area MoSe□, advancing the scalable fabrication of high-performance 2D materials for electronic and optoelectronic applications.